Update on the Measurement of the Branching Ratio of $D^0 \rightarrow K^+\pi^-$ to $D^0 \rightarrow K^-\pi^+$

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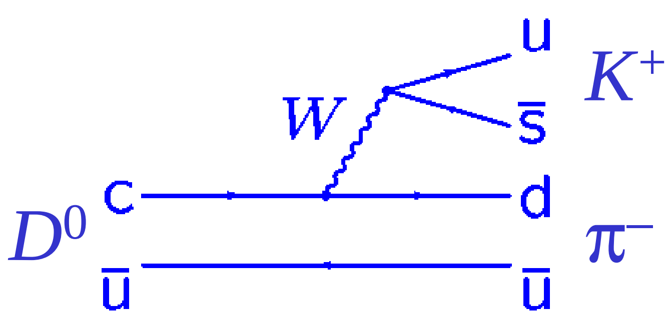
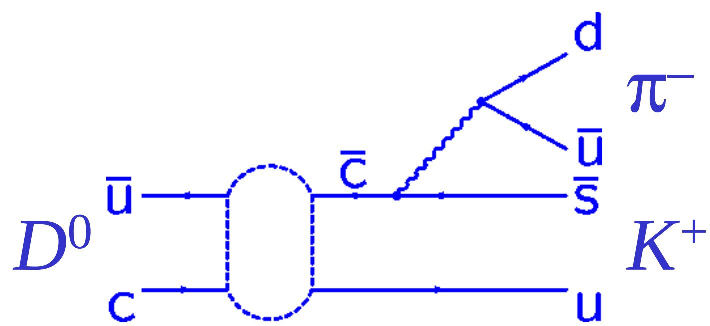
D^0 g $K^+\pi^-$ Can Occur Through

Double Cabibbo Suppression (DCS)

or

Mixing
Followed by a Cabibbo Favored Decay (CF)





Standard Model predictions for contributions to the relative branching ratio.

$\tan^4 ?_C \approx 0.25\%$

10^{-7} to 10^{-3}

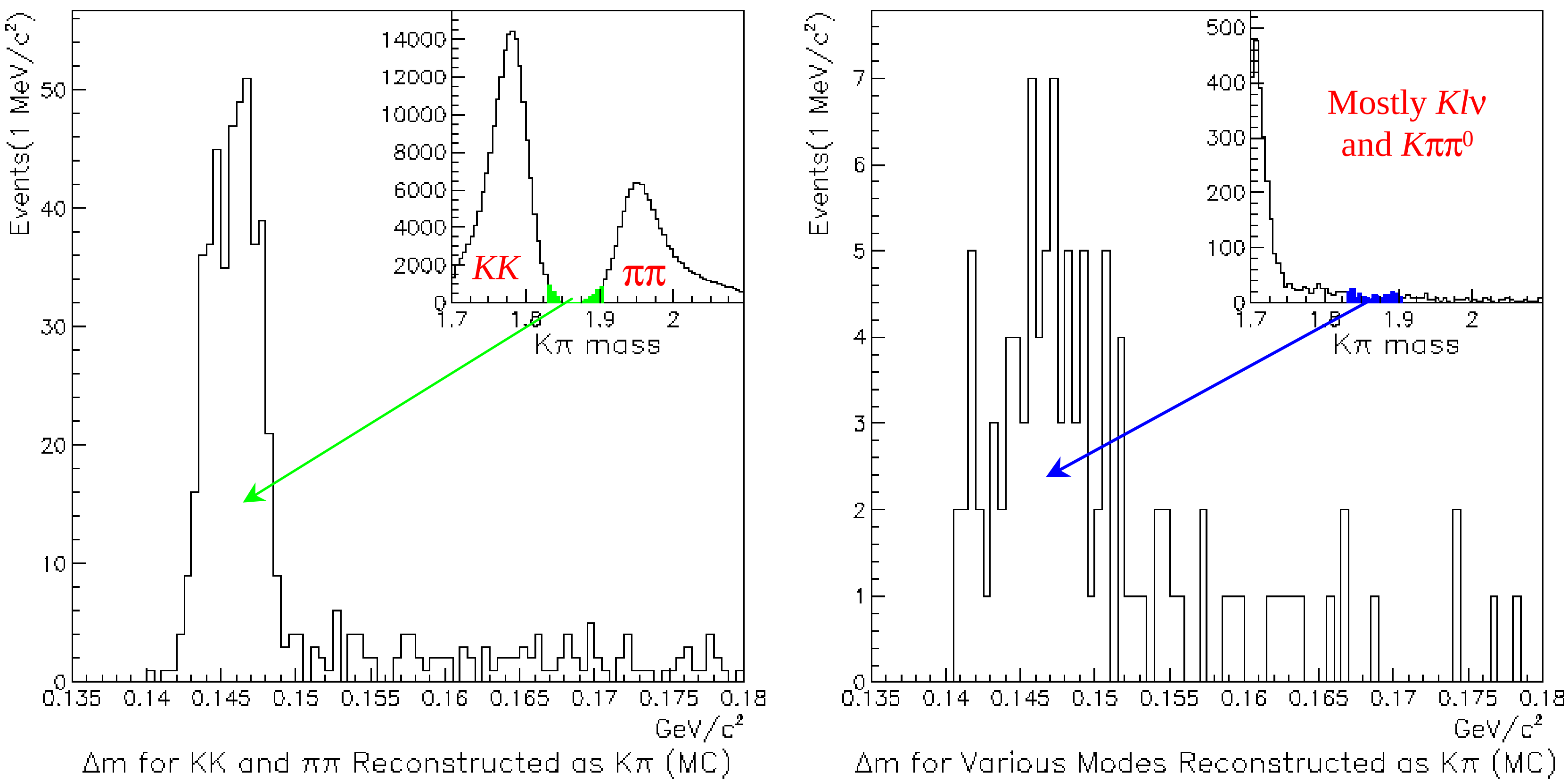
In this study we measure the branching ratio r_{DCS}=DCS/CF.

Event Selection

- Loose Wobs cuts: $\Delta W_K > 1/2$ and $\Delta W_\pi > -2$, all tracks have consistency>–4.
- The primary has at least 2 tracks in addition to the D^0.
- The primary is in target >–1σ.
- ISO1 < 10%
- $L/\sigma_L > 5$.
- $p_D > -160.+280.\mathrm{abs}(p_K - p_\pi)/(p_K + p_\pi)$
- All tracks have $CL_\mu < 1\%$.
- Soft π is singly ionized.
- Soft π is not identified as an electron by Cerenkov and EM calorimeters.

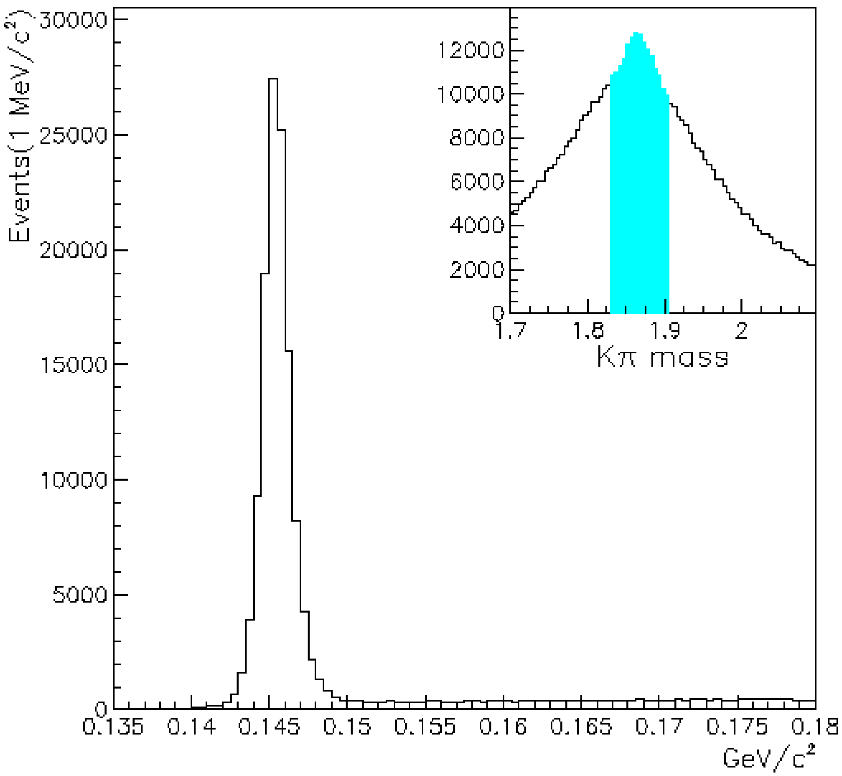
Monte Carlo Background Studies

Backgrounds from other D^0 decays peak in the D^* signal region!



If not dealt with these backgrounds could seriously bias an analysis.

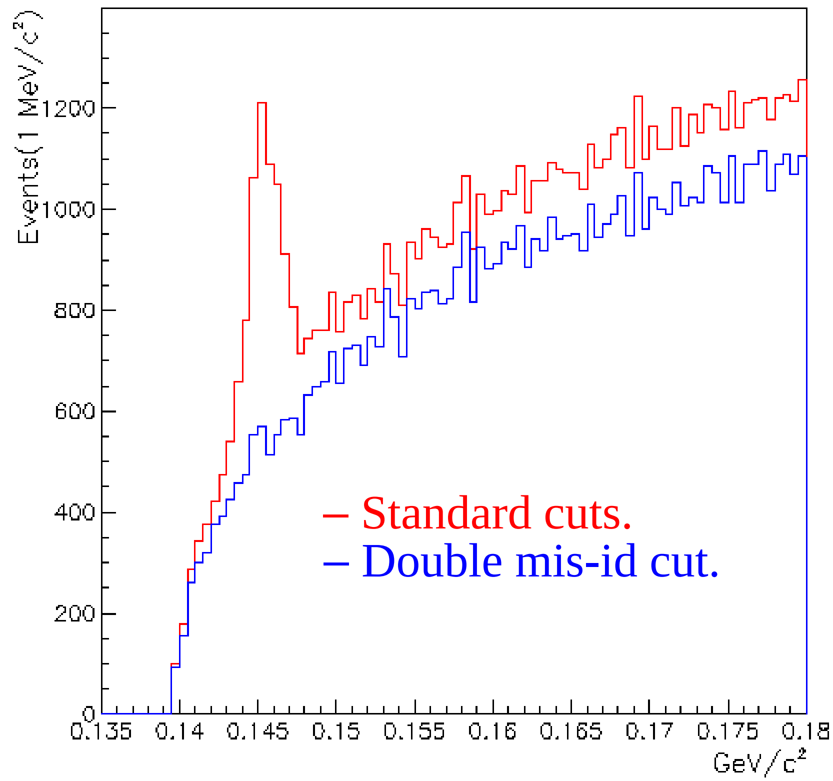
The Worst BG is CF $K\pi$ Double Mis-id



Δm for CF Reconstructed as DCS (MC)

The double mis-id Δm is indistinguishable from the correctly identified signal.

So we use a tight Cerenkov based mis-id cut in a $\pm 4\sigma$ window about the D^0 with $K\pi$ reconstructed as πK.



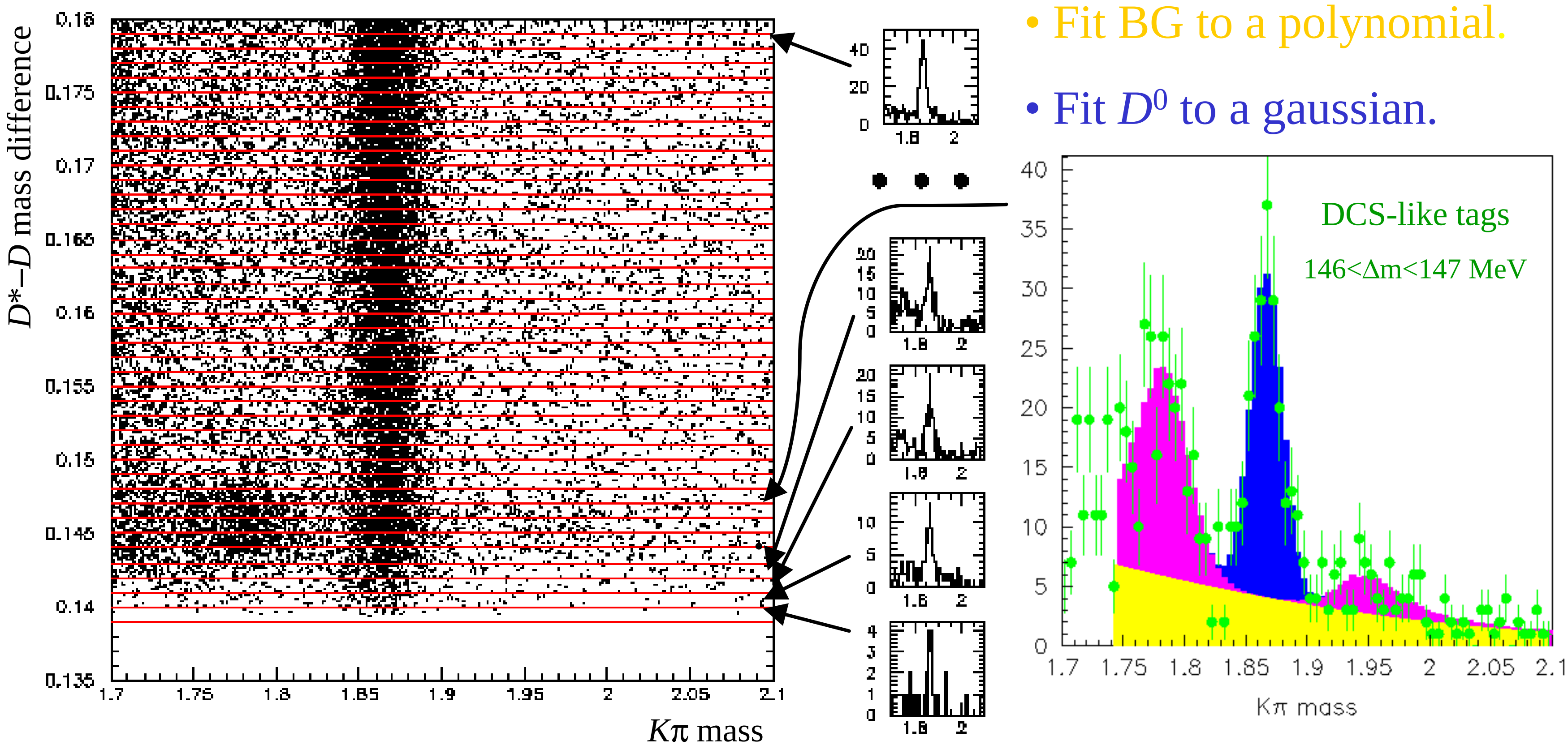
Δm for DCS from a CF MC

How do we Treat The Other Mis-id BG's?

- We could target K^+K^- and $\pi^+\pi^-$ just like we did with $K^-\pi^+$.
  This carves holes in the D^0 sidebands.
- We could use hard Cerenkov based id cuts everywhere.
  A big hit in yield and very little improvement in S/N.
- Try something completely different.

A New Method

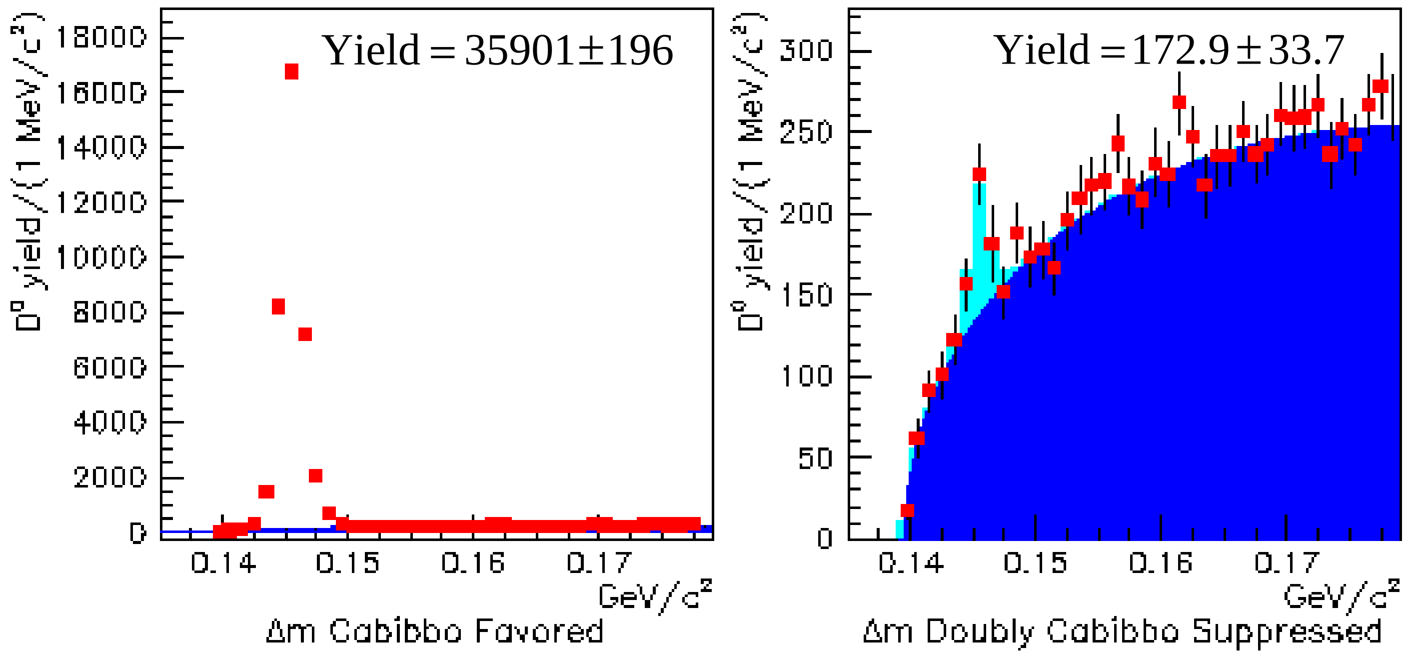
- Divide the data into 1 MeV wide bins in Δm, and fit the D^0 in each bin.
- Fit the *KK* and ππ reflections with Monte Carlo events.
- Fit BG to a polynomial.
- Fit D^0 to a gaussian.



A total of 80 fits!

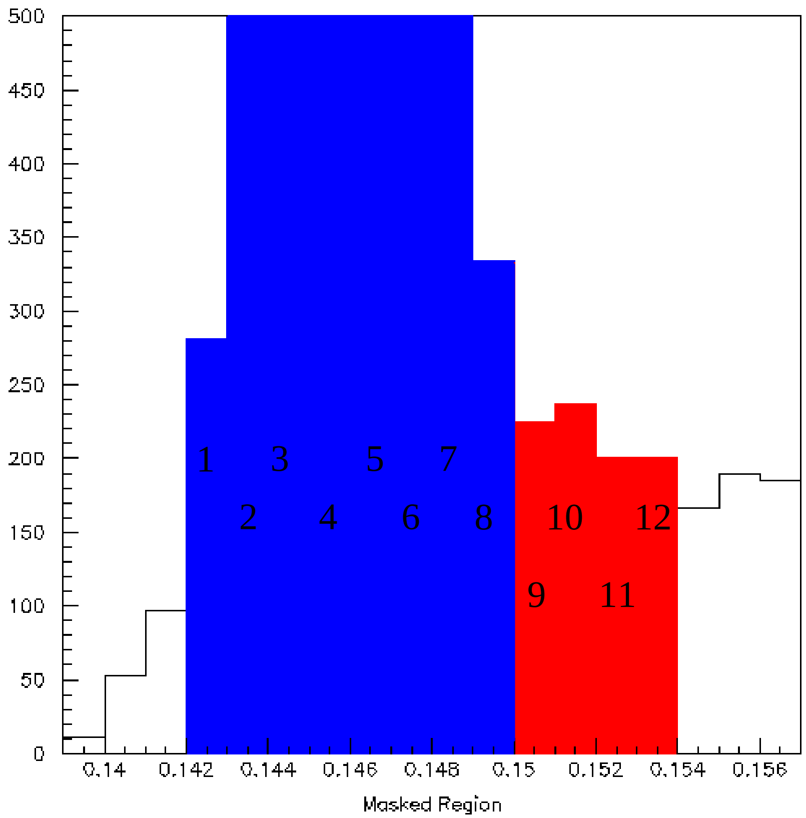
Fit the Δm Distributions

- Fitted D^0 yields are plotted in the appropriate Δm bins.
- Background is fit to: $f(m) = a(m-m_p)^{1/2} + b(m-m_p)^{3/2}$.
- DCS signal is fit directly to the CF histogram signal region.



r_{DCS}= (0.482±0.093)%

How Wide Should the Masked Region Be?



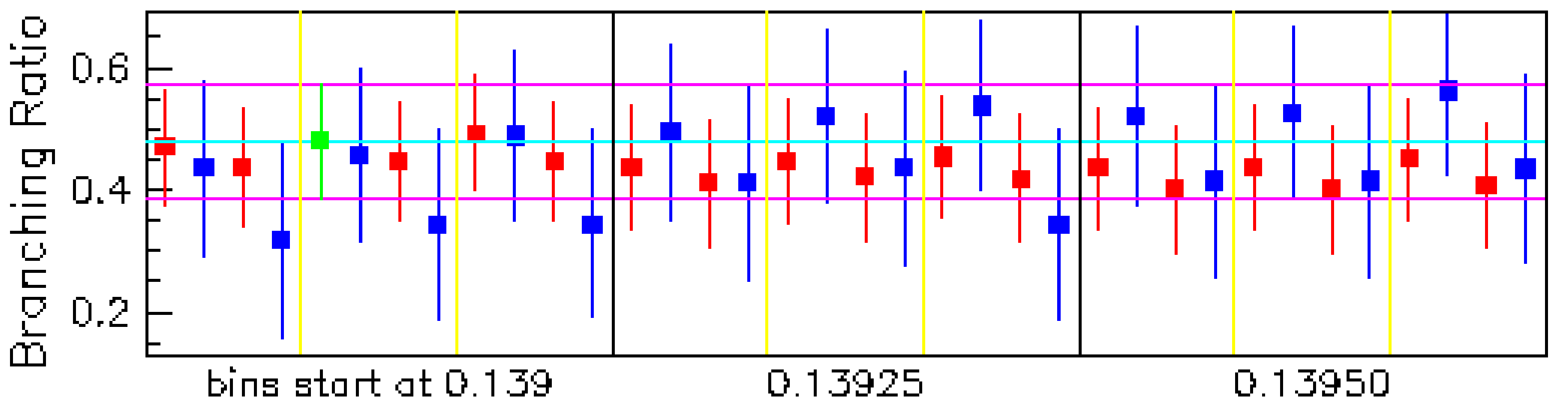
# Points	BR (%)	X^2/ndf
8	0.456±0.094	85.0/69
9	0.468±0.094	78.4/68
10	0.482±0.094	70.0/67
11	0.485±0.094	69.7/66
12	0.486±0.094	69.6/65

The branching ratio stabilizes with a mask of 10 points, and the X^2/ndf of the fit is smallest with a mask of 10 points.

Systematic Error Studies

Fit Variants:

1. Shift bin centers (Bins start at 0.139, 0.13925 and 0.1395).
2. Vary total number of points in BG (38, 40 and 42).
3. Fit WS and RS Backgrounds together and separately.
4. Count entries above BG in signal region.



$\sigma_{\text{fit sys}}$= 0.0529% total

But the fit systematic method of Jim and Rob does not account for the size of the errors!

$\sigma_{\text{fit sys}}$= 0.0261% without counting method

Cut Variant Systematic Study

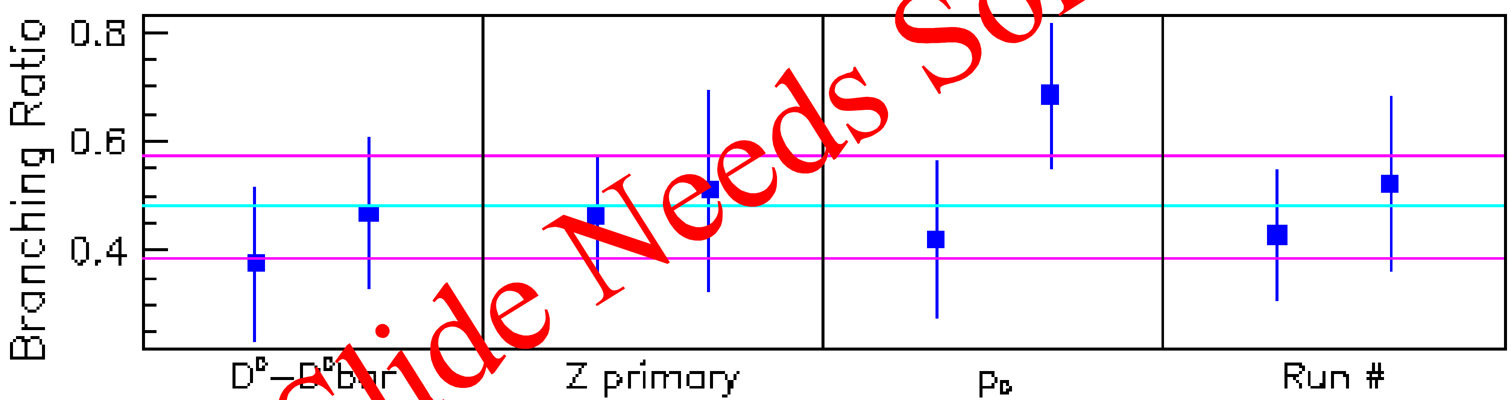
Variant	Branching Ratio (%)
No electron id on soft π	0.4795 ± 0.1040
No asymmetry cut	0.4569 ± 0.0973
No CL_μ cut	0.4785 ± 0.0957
No multiplicity of primary cut	0.4785 ± 0.1050
Primary in target > 0σ	0.4762 ± 0.0957
Primary in target >-1.5σ	0.4895 ± 0.0953

$$\sigma_{\text{cut sys}} = 0.0099\%$$

Split Sample Systematic

- D^0-D^0bar
- Z primary > and < –3.75
- p_D > and < 75 GeV
- Run Number > and < 9750

This Slide Needs Some Work!



$\sigma_{split\ sys} = 0.0337$ ($< \sigma_{stat} = 0.0937$)

$\sigma_{split\ sys} = 0.0937$ (p_D only)

Any way you look at this it is still not larger than σ_{stat}.

Total Systematic Error

If I use my favored estimates of systematic error

$\sigma_{\text{fit sys}} = 0.0261\%$ $\sigma_{\text{cut sys}} = 0.0099\%$ $\sigma_{\text{split sys}} = 0.0\%$

Then…

$\sigma_{\text{total sys}} = 0.0279\%$

And the branching ratio with full errors would be…

$$r_{DCS} = (0.482 \pm 0.093 \pm 0.028)\%$$

Possible Effects of Mixing

- If charm mixing is significant then decay rate as a function of time is:

$$r(t/\mathrm{t}) = \left\{ r_{DCS} + \sqrt{r_{DCS}}\, y'(t/\mathrm{t}) + \frac{\left(x'^2 + y'^2\right)}{4}(t/\mathrm{t})^2 \right\} e^{(-t/\mathrm{t})}$$

- With $x' \equiv x\cos \mathrm{d} + y \sin \mathrm{d}$, $y' \equiv y \cos \mathrm{d} - x \sin \mathrm{d}$,

$x \equiv \dfrac{\Delta m}{\Gamma}$, $y \equiv \dfrac{\Delta\Gamma}{2\Gamma}$ and δ is the strong phase.

- The measured BR depends on the lifetime acceptance of the analysis.

- We use a D^0 **g** $K^-\pi^+$ Monte Carlo to study the effects of mixing on the measured BR (r_{meas}).

$$\left(D^0 \to K^+\mathrm{p}^-\right)^{expected}_{data} = \sum_{i}^{MCaccepted} W\left(t_i, x', y', r_{DCS}\right)$$

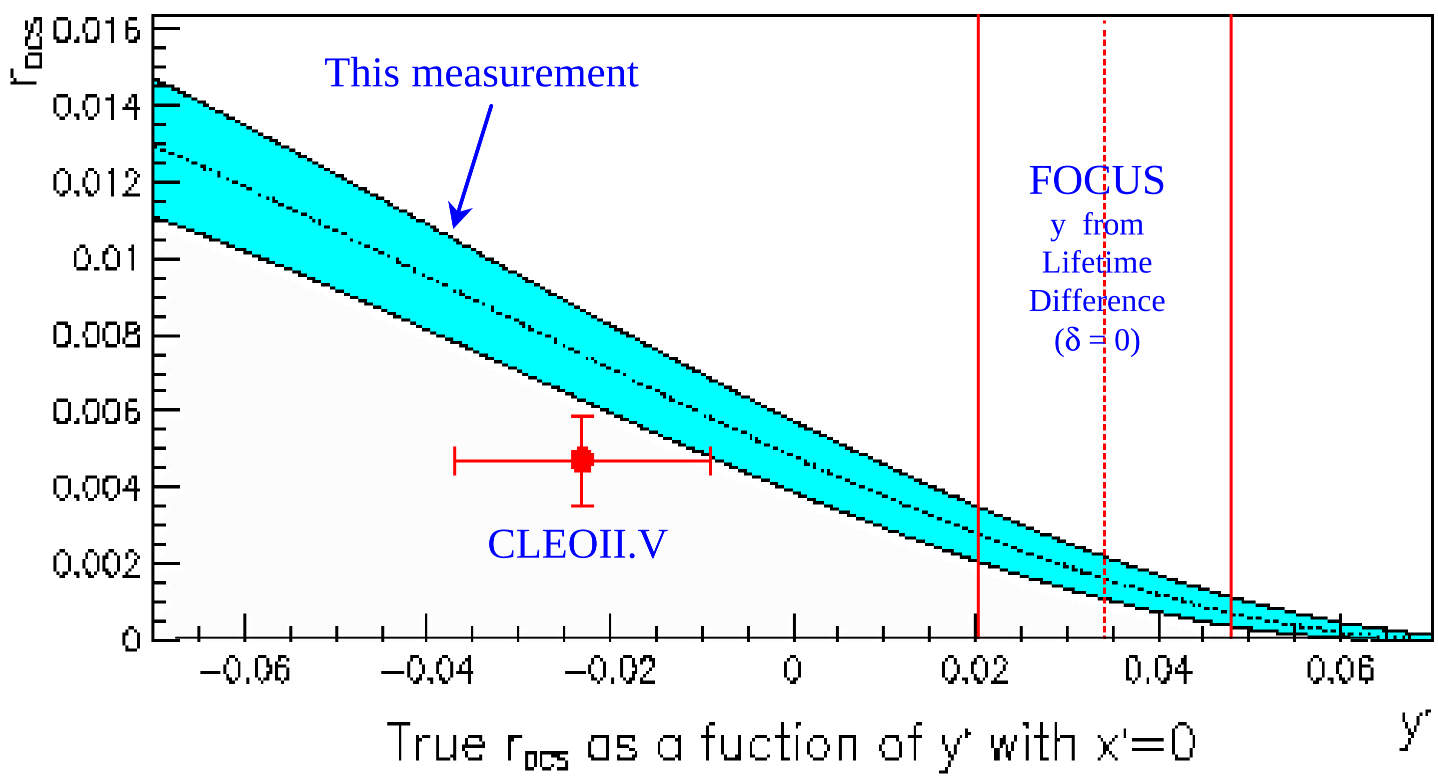
- Where

$$W\left(t, x', y', r_{DCS}\right) = \frac{CF^{accepted}_{data}}{CF^{accepted}_{MC}} \left(r_{DCS} + \sqrt{r_{DCS}}\, y'(t/\mathrm{t}) + \frac{\left(x'^2 + y'^2\right)}{4}(t/\mathrm{t})^2 \right)$$

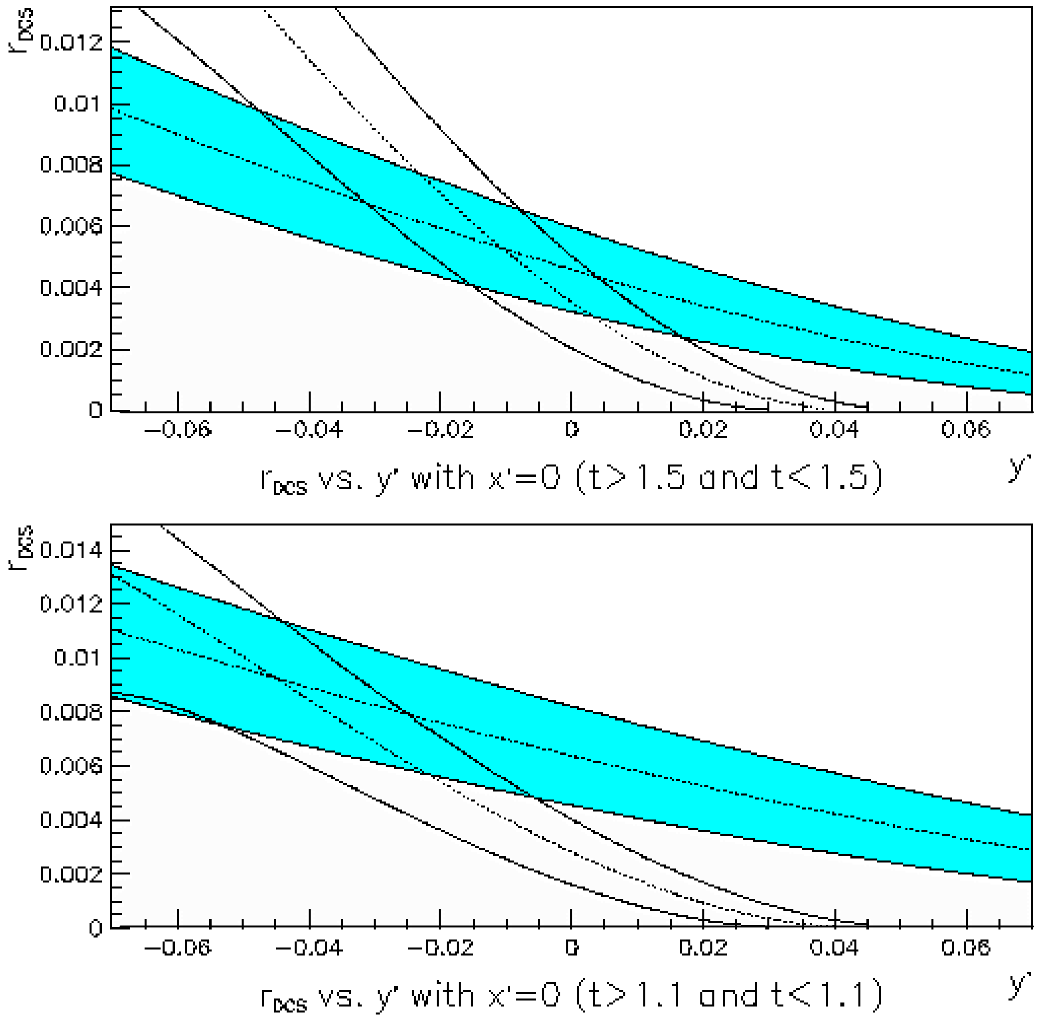
Effects of Mixing Continued

- We find r_{DCS} as a function of x', y' and r_{meas}…

$$r_{DCS} = y'^2 \langle t/\mathrm{t} \rangle^2 - \frac{(x'^2+y'^2)}{4} \left\langle (t/\mathrm{t})^2 \right\rangle + r_{meas} - \frac{y'}{2} \langle t/\mathrm{t} \rangle \sqrt{y'^2 \langle t/\mathrm{t} \rangle^2 - (x'^2+y'^2) \left\langle (t/\mathrm{t})^2 \right\rangle + 4r_{meas}}$$



A First Attempt at a Mixing Study



The data is split into 2 sets based on lifetime t.

The analysis is run on each data set.

The mixing curve of both sets are plotted on top od each other.

I looked at two different time splits.

Both splits favor negative y', but they are also consistent with zero or even +0.02.

Conclusions

- I measure the branching ratio to be:

$$r_{DCS} = (0.482 \pm 0.093 \pm 0.028)\%$$

- I'm not yet satisfied with the mathematics of the systematic error.

- Early mixing studies using this method don't appear to be very sensitive, but they do prefer a negative value of y'.